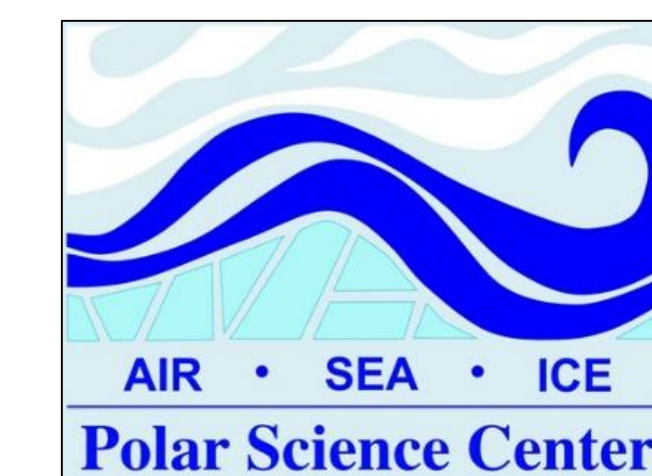


Navigability Indicators for the Northwest Passage and the Northern Sea Route

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Introduction

National Climate Assessment (NCA). The U.S. NCA [Melillo et al., 2014] acts as a national climate snapshot or status report. Climate “indicators” for the NCA are designed to quantify clearly and concisely the status and trends of various elements of the climate system and their biological significance.

Northwest Passage (NWP) and Northern Sea Route (NSR). The NWP and NSR are sea routes across portions of the Arctic Ocean that connect the Atlantic and Pacific Oceans. The NWP passes through the Canadian Arctic Archipelago, and the NSR passes north of Russia.

Navigability indicators. We are constructing navigability indicators for the NWP and NSR that indicate the percentage of the route’s length that is free enough of sea ice to allow the passage of a ship. The navigability indicators change daily as sea-ice conditions change.

Arctic marine mammals. All seven of the marine mammal species that live in the Arctic year-round (beluga, narwhal, bowhead whale, ringed seal, bearded seal, walrus, and polar bear) occupy portions of both the NWP and the NSR. We are identifying and mapping key areas of their habitat that intersect the routes of the NWP and NSR, and constructing vulnerability indexes for up to 80 distinct populations, to see which populations might be impacted by increased shipping and industrial development as Arctic sea ice continues to decline.

Methods

Sea-ice data. We use daily sea-ice concentration products derived from the passive microwave sensor AMSR-E on NASA’s Aqua satellite, obtained from the Centre for Marine and Atmospheric Sciences in Hamburg, Germany [Spreen et al., 2008]. Data are mapped to a polar stereographic grid with 6.25-km grid size, and are available from June 2002 to October 2011. AMSR-2 and other data will be used to extend results beyond 2011.

For narrow passages such as Bellot Strait we use visible-band images from MODIS on NASA’s Terra and Aqua satellites (250-meter pixel size) and very high resolution (3-meter pixel size) visible images from Planet.com [Planet Team, 2017].

Navigability indicators. We outline the routes of the NWP and NSR on a base map using ArcGIS, extract the sea-ice data from within the route boundaries, and calculate the navigability indicators from the time series of sea-ice data within the routes.

Arctic marine mammals. Data on the ranges of Arctic marine mammals have been gleaned from an extensive literature search: 110 sources for cetaceans, 81 sources for pinnipeds, and 60 sources for polar bears [see Laidre et al, 2015]. We focus on September, the month most likely for shipping activity through the NWP and NSR.

Results – see panels to the right →

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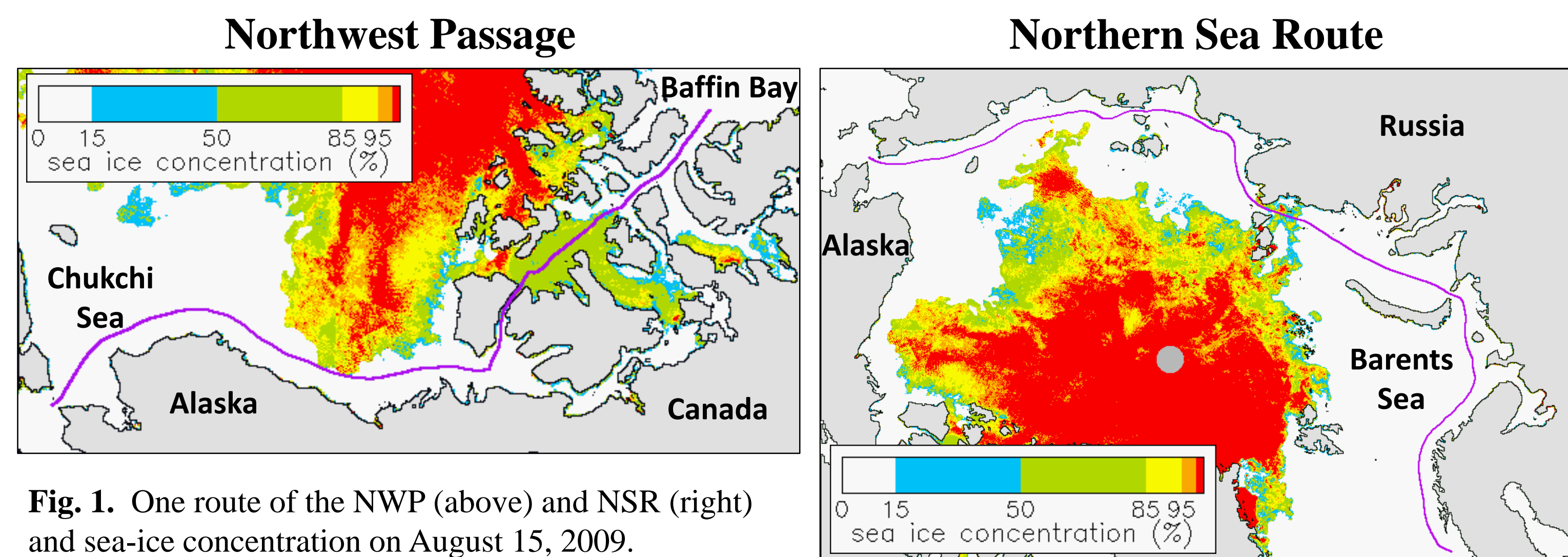


Fig. 1. One route of the NWP (above) and NSR (right) and sea-ice concentration on August 15, 2009.

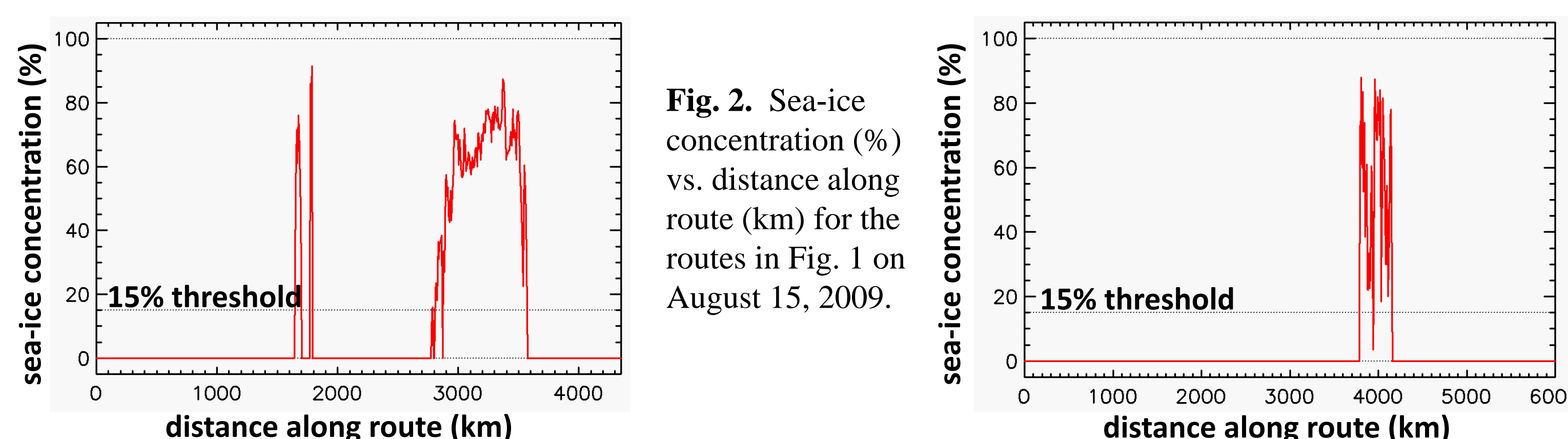


Fig. 2. Sea-ice concentration (%) vs. distance along route (km) for the routes in Fig. 1 on August 15, 2009.

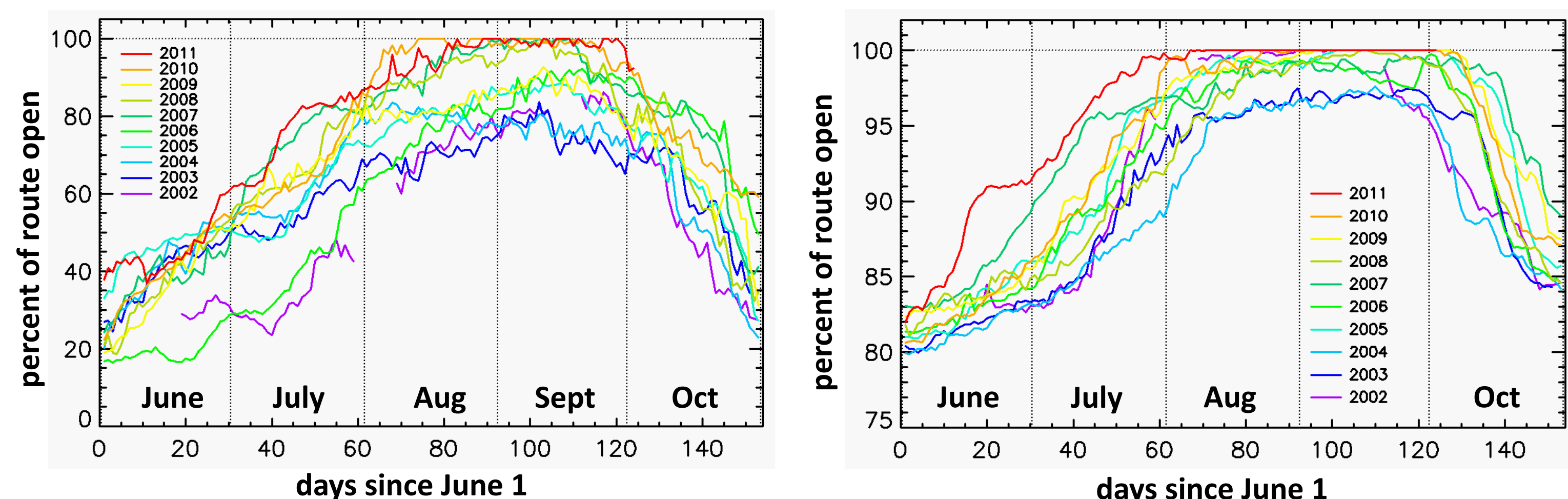


Fig. 3. Percent of route with < 15% sea-ice concentration during June-October, for the years 2002-2011.

Results. The method for calculating navigability indicators is illustrated above. One route through the NWP and NSR is shown, along with sea-ice concentration for August 15, 2009 (Fig. 1). The sea-ice concentration as a function of distance along the route (Fig. 2) shows that the NWP route is blocked in Viscount Melville Sound, and the NSR route is blocked at Vilkitsky Strait. The percentage of the route that is open from June-October, 2002-2011 (Fig. 3), shows dramatic changes over this 10-year period, with both routes transitioning from < 100% in the early years (i.e., never fully open) to long stretches of 100% in the later years.

High Resolution Visible Imagery

Bellot Strait, which connects Peel Sound and Prince Regent Inlet in the NWP, is 25 km long and only 2 km wide, so it cannot be resolved by the passive microwave sea-ice data. MODIS imagery is useful, but still the strait is only 8 pixels wide. With imagery from Planet.com, detailed patterns of sea ice within the strait can be seen.

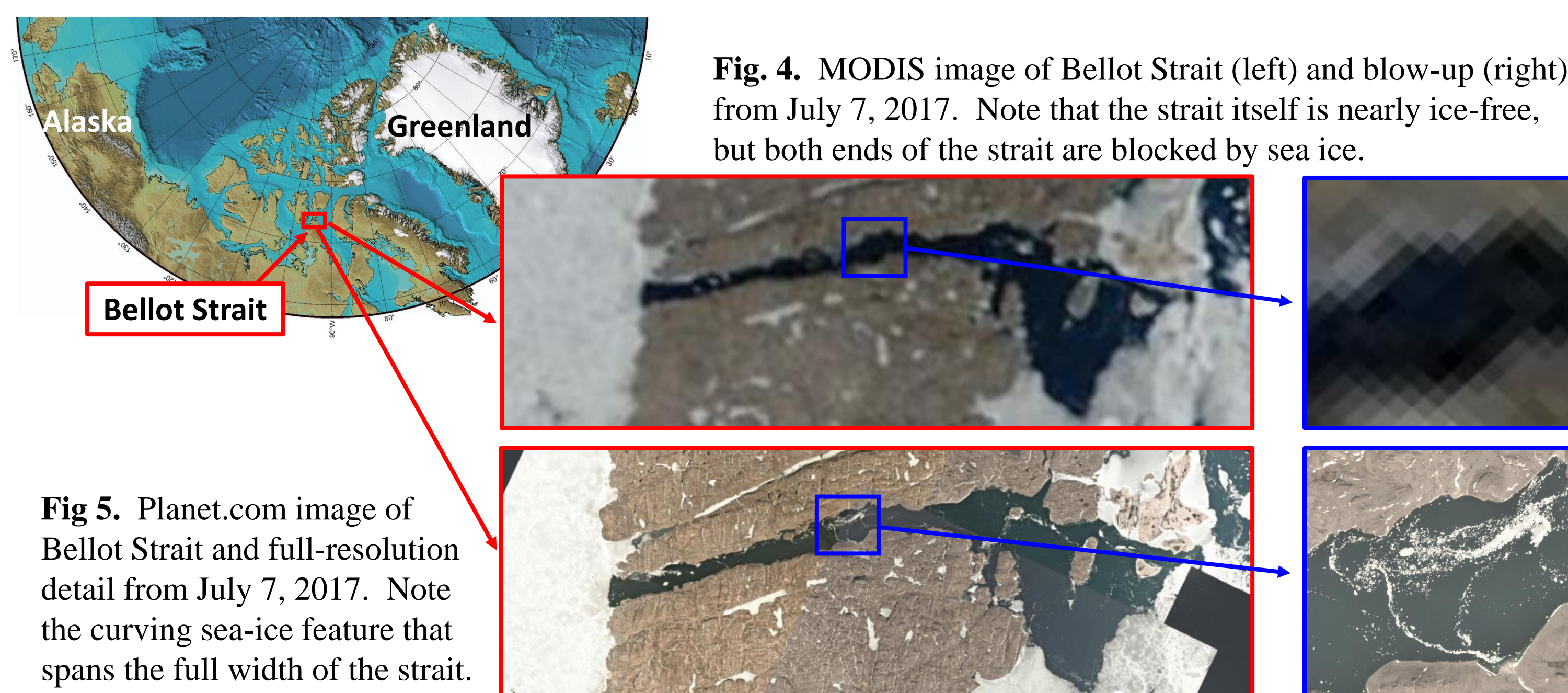


Fig. 4. MODIS image of Bellot Strait (left) and blow-up (right) from July 7, 2017. Note that the strait itself is nearly ice-free, but both ends of the strait are blocked by sea ice.

Fig 5. Planet.com image of Bellot Strait and full-resolution detail from July 7, 2017. Note the curving sea-ice feature that spans the full width of the strait.

Arctic Marine Mammals

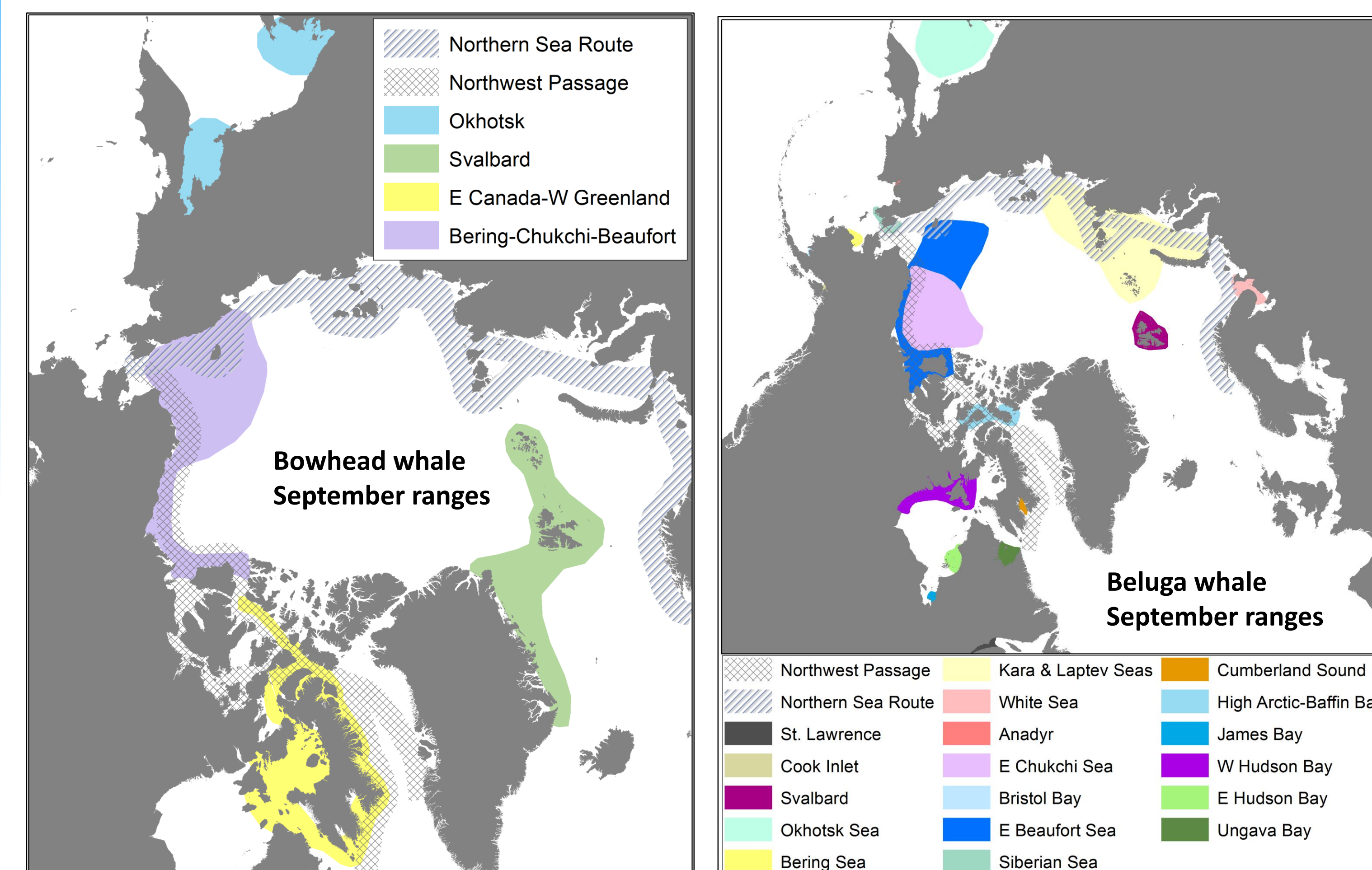
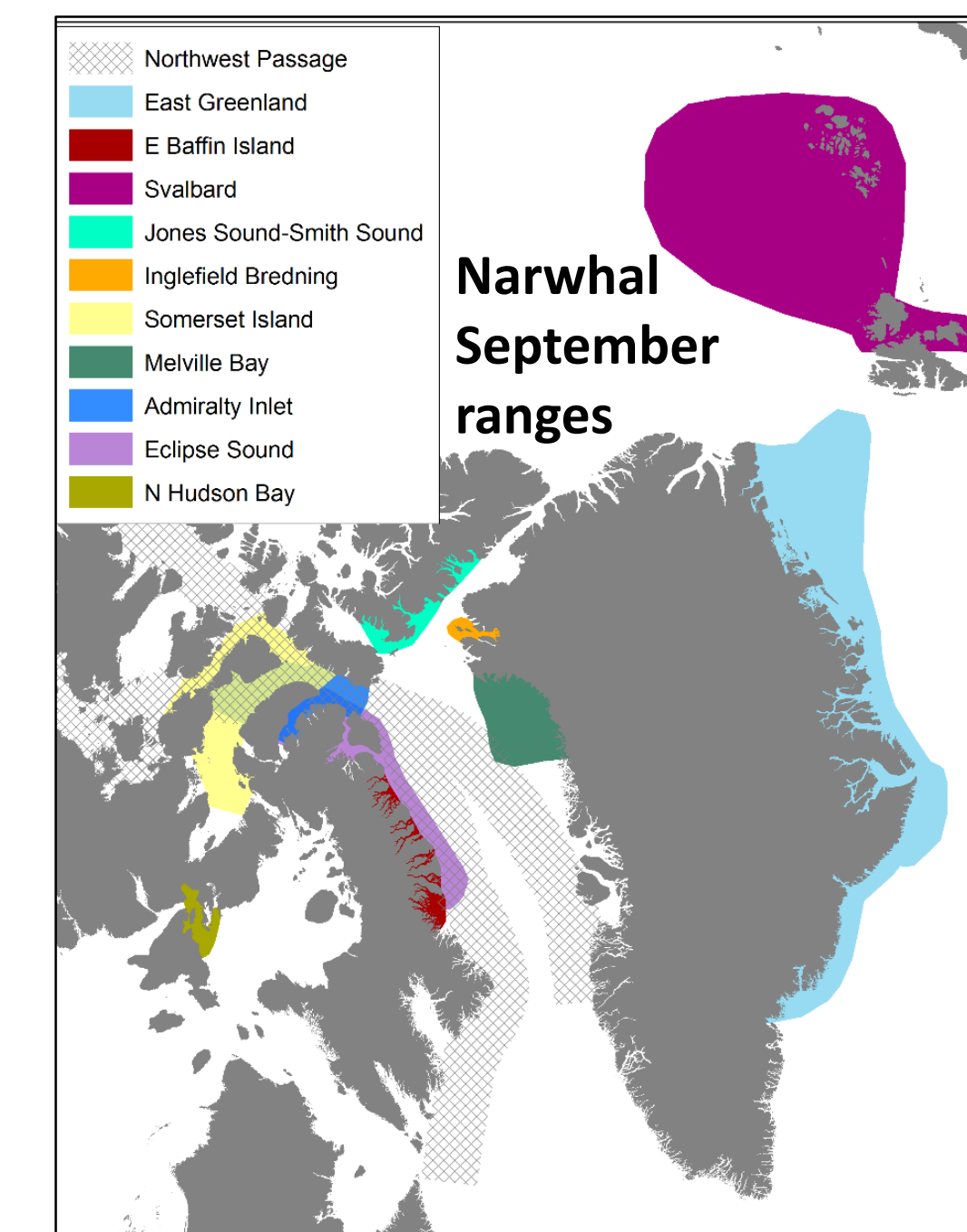


Fig. 6. Three populations of bowhead whales (upper left), five populations of beluga whales (upper right), and four populations of narwhals (left) inhabit parts of the NWP and NSR during the time of year when sea ice is at its minimum level and shipping is likely to be at its maximum level.



Vulnerability indexes. Vulnerability (V) measures the susceptibility or risk of a population to impact, often defined as the combined effect of exposure (E) and sensitivity (S) to a particular hazard [Williams et al., 2008; Turner et al., 2003], expressed as $V = E \times S$. We are creating vulnerability indexes for each population above. We estimate exposure based on spatial overlap of vessel routes and population distribution. We estimate sensitivity based on the literature, using a scoring system to account for potential individual and population-level consequences of exposure to marine traffic, incorporating variables such as susceptibility to acoustic disturbance and lethal ship strikes. We are exploring how to incorporate uncertainty into vulnerability, and how to scale up the population vulnerability to the species level.

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We thank the Planet Team for access to high resolution images.



Fig. 8. Ship tracks in the Arctic in September 2016 from the Norwegian Havbase database at https://havbase.no/havbase_arktis.

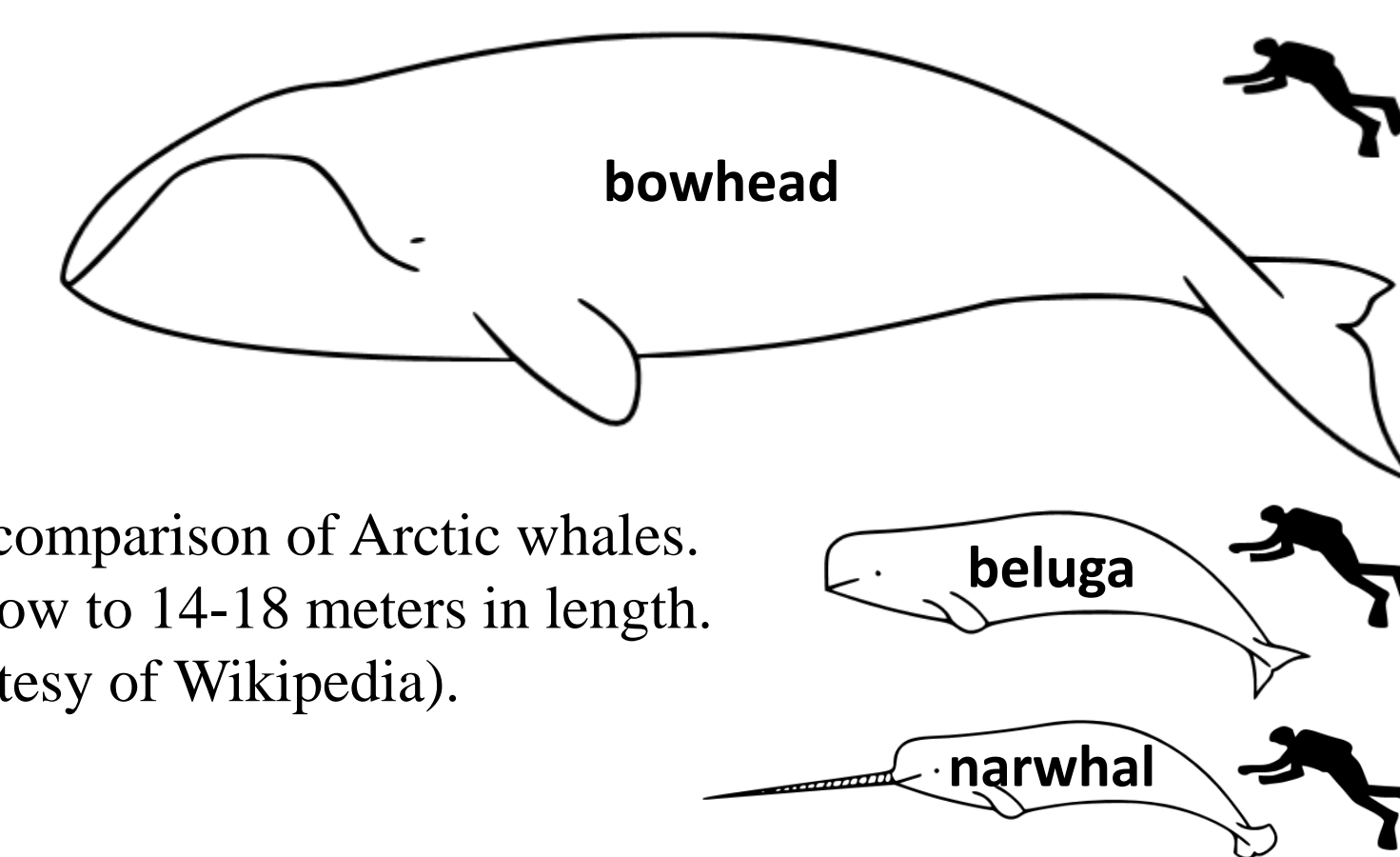


Fig. 7. Size comparison of Arctic whales. Bowheads grow to 14-18 meters in length. (Images courtesy of Wikipedia).